An Unusual Case of Carbon Monoxide Poisoning

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Carbon monoxide, a gas originating from incomplete combustion of carbon-based fuels, is an important cause of human deaths. In this paper, we describe an unusual carbon monoxide poisoning in a dwelling without obvious sources of combustion gases, for which two adults had to be treated in a hyperbaric chamber. Carbon monoxide readings were taken in the house and in the neighboring homes. Methane gas and nitrogen oxide levels were also monitored in the house air. Soil samples were collected around the house and tested for hydrocarbon residues. The investigation revealed the presence of a pocket of carbon monoxide under the foundation of the house. The first readings revealed carbon monoxide levels of 500 ppm in the basement. The contamination lasted for a week. The investigation indicated that the probable source of contamination was the use of explosives at a nearby rain sewer construction site. The use of explosives in a residential area can constitute a major source of carbon monoxide for the neighboring populations. This must be investigated, and public health authorities, primary-care physicians, governmental authorities, and users and manufacturers of explosives must be made aware of this problem. *Key words*: carbon monoxide, dwelling, explosives, geology, poisoning. *Environ Health Perspect* 107:603–605 (1999). [Online 16 June 1999]
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Carbon monoxide (CO) is a colorless, odorless, and tasteless gas originating mainly from the incomplete combustion of carbon-based fuels (*1*). Between 1979 and 1988, 11,547 deaths due to accidental CO poisoning were recorded in the United States. Of these, 6,552 (57%) were due to exposure to motor vehicle exhaust. The other 4,995 cases were related to another source: a home heating appliance (1,199), combustion of natural gas distributed by pipeline (578), the combustion of liquefied petroleum gas or another utility gas in mobile containers (469), or industrial processes (187). The source was not specified in 2,302 deaths (*2*). In this paper, we describe the environmental investigation of a case of CO poisoning in two people, which was probably due to the use of explosives on a rain sewer construction site in a residential area.

Case Presentation

On 30 April 1995, around 8:00 P.M., a 33-year-old man and a 29-year-old woman suffering from severe headaches, extreme fatigue, dizziness, nausea, and palpitations were brought to the emergency room of a hospital in Quebec City, Quebec, Canada. The man had awakened around 3:00 A.M. the previous night with a severe frontal headache. He also lost consciousness for several minutes. The symptoms lasted throughout the day, and the couple thought they were suffering from food poisoning. That evening, a relative drove them to the hospital.

Blood samples were taken from the man and woman approximately 2 hr after they left their home. Laboratory findings, including arterial blood gases, blood urea nitrogen, blood creatinine, blood electrolytes, plasma glucose concentration, and hemoglobin and white blood cell counts were all normal. However, the carboxyhemoglobin (COHb) level was 29.6% for the man and 24.7% for the woman. CO poisoning was diagnosed and the patients were transferred to a hyperbaric chamber, mainly because of the episode of loss of consciousness in the male. Three weeks later, they were seen on follow-up and they were completely asymptomatic.

On 1 May, the case was referred to the public health authorities for investigation. The house was an 8.6-m × 9.8-m bungalow with an unfinished basement whose walls were covered with Styrofoam insulation and gypsum board. There was no attached garage or other obvious sources of combustion products. The victims recounted that on 27–29 April, explosives had been used for blasting a trench on a nearby rainfall sewer construction site. The last explosive charges had been laid around 5:00 P.M. on Saturday, 29 April, opposite the southeast corner of their house. During the final explosion, the woman recalled hearing a cracking sound coming from the foundation of the house in the direction where the men were working.

CO was first measured inside the house by a fireman wearing a self-contained breathing apparatus with a personal CO monitor (Datalogger 190; Dräger, Pittsburgh, PA). This apparatus operated by means of an electrochemical cell; its scale was 0–999 ppm, with a precision of ± 2 ppm and an accuracy of ± 5% (*3*). However, it was sensitive to interference from other gases, particularly certain hydrocarbons. Following the results of the first sampling inside the house, other readings were also taken outside using tygon tubing in the three window wells near the foundation, at a depth of 15 cm in the crushed stone. Other readings were also taken in the rain and sanitary sewers in the area and in the basements of seven neighboring dwellings. Finally, a continuous sampling program was conducted in the victims' residence, and readings were taken for periods of 2–12 hr/day from 1 May to 10 May.

To identify the source of the contamination and to ensure the accuracy of data, CO and methane (CH_4) concentrations were measured continuously from 7:00 P.M. on 4 May until 1:00 A.M. on 7 May using a Fourier Transform Infrared Spectrophotometer (FTIR; Bomem, MB, Sainte-Foy, Québec, Canada) (*4*). The data were integrated using automated data-collection software (GRAMS/386; GRAM Galactic Industries, Inc., Salem, NH). The detection limits were 0.5 ppm for CO and 3 ppm for CH_4. Nitrogen oxides (NO_x) were also monitored on 2 May with colorimetric tubes (Dräger CH31001), with a scale from 2 to 50 ppm (*5*). Also, because municipal authorities suspected that the house was built on a site where petroleum products may have been dumped, soil core samples were collected near the house and sent to a specialized laboratory. An FTIS (FTIR1600; Perkin-Elmer, Norwalk, CT) was used to identify any contamination by mineral oils or greases (*6*). Benzene, toluene, ethyl benzene, and xylene were monitored with a gas phase chromatograph (5890 series II; Hewlett Packard, Little

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Falls, DE) equipped with a mass spectrometer (Hewlett Packard 5971A) (*6*); the presence of petroleum products was verified with a gas chromatograph (Varian 3400; Varian, Walnut Creek, CA) with a flame-ionization detector (*6*).

Figure 1 represents the plan of the house and the locations with the highest CO levels in the initial readings taken on 1 May. In the basement, the first readings at point A (southeast corner) and point B (floor drain) were 367 and 500 ppm, respectively. Interestingly, the sample taken at point C (east window well outside the house) showed a high concentration of 250 ppm. At this moment, all readings in neighboring basements, in rainfall, and in sanitary sewers, as well as in other locations around the foundation, including the north and west window wells (Figure 1), indicated no CO. We concluded that a pocket of gas was probably located under the southeast foundation of the house. The CO most likely entered the house from the floor drain and an invisible crack (not seen because of the wall covering) in the eastern section of the foundation.

After this initial sampling, the windows of the house were opened. Due to the slight reduction in CO levels, the foundation on the east side of the house was excavated near the window well (point D in Figure 1) on 3 May. Samples collected at this time in the trench gave concentrations of CO up to 700 ppm. On 4 May, a second excavation was done on the west side (point E in Figure 1), and ventilation pipes paired with mechanical ventilation were installed under the foundation of the house. The CO concentrations dropped progressively until 6 May, the day when contamination could no longer be detected. The windows were then closed and CO monitoring of the ambient air continued for another 4 days without any gas being detected. Figure 2 summarizes the results of the CO monitoring program in the southeast corner of the basement of the house, as well as the chronology of the events that punctuated the interventions. Every day, the readings were generally higher at the start of sampling and then dropped slowly. Only the highest daily results are presented.

On 2 May, NO_x (NO and NO_2) was not detected. Readings were taken between 4 May and 7 May. The data collected by FTIR inside the house revealed CH_4 concentrations on 4 May between 8 and 10 ppm, which slowly dropped to the levels documented outdoors (< 3 ppm). CO levels were identical to those measured by photochemical cell (Figure 2).

All the soil analyses indicated no oil or aromatic hydrocarbons that are generally present in gasoline (toluene, xylene, benzene, ethyl benzene) or any petroleum products.

Discussion

Based on the victims' symptoms (*7*) and the relationship between the COHb levels and the CO exposure in the ambient air, the victims' exposure was estimated as having been high enough to raise their COHb levels 40–50%, for an exposure of approximately 500 ppm for over 16 hr (*8*). Data collected in the house confirm this possibility (Figure 2), and the entire sampling strategy clearly indicates that the gas entered the house from the southeast section of the basement. Different scenarios emerged to explain this phenomenon.

First, we investigated the possibility of petroleum waste combustion; this was rejected on the basis of the soil analysis results. We then investigated the possibility of a natural pocket of CH_4 in the soil following the use of explosives. We rejected this assumption on the basis of the CH_4 sampling results, which showed that the concentration in the house was too low.

We then examined the possibility that the contamination originated exclusively from explosives. Two products had been used in the excavation work: a mixture of ammonium nitrate, sodium nitrate, and fuel oil (Apex Ultra 40; ICI Canada, Inc., North York, Ontario, Canada), and a mixture of ethylene dinitrate and glycol/nitroglycerine (POWER FRAC; ICI Canada, Inc.). According to the manufacturer's laboratory data, these mixtures have a negative oxygen balance, which means that they produce little or no NO_x. However, they generate CO on the order of 15.9 L/kg for Apex Ultra 40 and 22.4 L/kg for POWER FRAC. Following a calculation integrating the quantity of explosives used for all of the excavation work, as well as the dimensions of the house, we concluded, based on the laboratory data, that the quantities of CO generated could not have increased the concentrations in the house to the levels documented in Figure 2. However, apart from the chemical compositions of the products used, many variables can affect the release of toxic gases by blasting agents (*9*). We therefore believe that other factors also interacted to increase the quantities of CO produced. For example, the contractor was behind schedule and set the explosives under a thick layer of overburden. These conditions are clearly very different from those of the laboratory tests. The presence of overburden very likely produced an oxygen deficiency

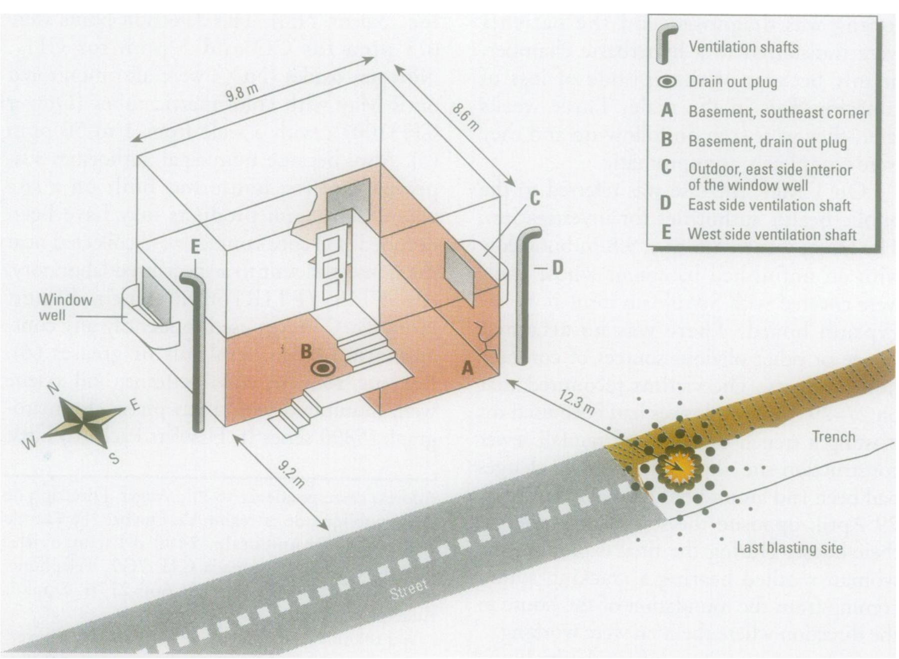

Figure 1. Graphic illustration of the house where exposure occurred.

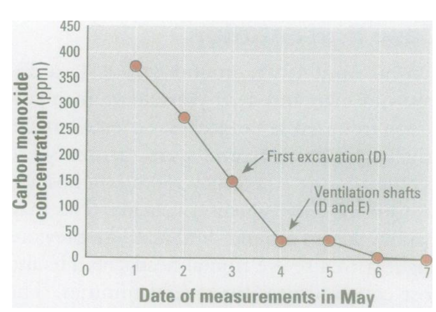

Figure 2. Highest carbon monoxide concentrations monitored in the basement of the house according to the daily readings. The locations of D and E are shown in Figure 1.

and increased the concentrations of CO generated by increasing the negative oxygen balance (*10*). Another variable to be considered is the type of rock where the blasting occurred; this rock was a limestone high in carbonates, which, with intense heat, may generate CO (*11*). In this case, the heat produced by the explosives may have been sufficient to produce this phenomenon.

Following the environmental investigation and the case review, we believe that the last explosion that occurred near the house (Figure 1) modified the rock structure under the house, which resulted in a large proportion of the CO gas generated by the excavation work under anaerobic conditions accumulating under the southeast corner of the house. Given the high concentrations of CO and the duration of contamination, other geological factors may also have been involved.

There is very little data in the literature pertaining to residential CO contamination following excavation work involving explosives. Dougherty et al. (*10*) described a similar incident in a southeastern Pennsylvania township. In 1988, following sewer construction work, two children were hospitalized with severe CO poisoning. Four houses were then investigated. Three of the houses were contaminated with high levels of CO up to 2,000 ppm. As in the current case, CH_4 was present in significant concentrations. Interestingly, no CO was detected in the fourth house, which was equipped with a radon mitigation system. Two different explosives were also used in Pennsylvania: a mixture of ammonium nitrate and fuel oil, which are relatively comparable to Apex Ultra 40 and trinitrotoluene (TNT). The explosive charges were also laid under a layer of overburden, thus favoring anaerobic conditions. Following an extensive investigation, Dougherty et al. (*10*) concluded that the explosives were the source of the contamination. In a report issued by the Ontario Ministry of Health (*12*), Hamilton municipal authorities reported that the occupants of a house in their municipality complained of dizziness and discomfort after sewer construction work began near their home. In this residence, the recorded CO level was 126 ppm, and unusually high levels were noted in three other houses. The authorities believed that the contamination was due to the explosives used for the excavation and to CO infiltration through the sewer discharge drains of the houses adjacent to the work (*12*).

Conclusion

CO poisoning is difficult to diagnose. Symptoms are nonspecific, and in many cases, it likely remains undetected, particularly if there is no obvious exposure to combustion gases. Even if all the underlying mechanisms are not understood, such as the significance of the geological characteristics and the conditions in which the explosives were used, the results of the investigation and the review of existing literature indicate that the use of explosives in a residential area can be a major source of CO exposure for the population. In the present case, as in the investigation by Dougherty et al. (*10*), the poisoning was serious enough to lead to hospitalization. Therefore, it is more than likely, given the significant use of explosives in our industrialized world, that many other unidentified incidents have occurred. More must be done to further investigate and better understand this problem. In the meantime, public health authorities, primary-care physicians, governmental authorities, and explosives manufacturers and users must be made aware that the use of explosives in residential areas may lead to significant CO exposure for the neighboring populations.

Update

Upon completion of this manuscript, we were made aware of a similar incident that occured at 6:00 P.M. on 10 November 1998 in a small town in the province of Québec, Canada. In this case, six houses were involved. CO readings varied from 125 to 600 ppm (Model 3005; Ames Multigas, Annacis Island, British Columbia, Canada). Six occupants of 16 were intoxicated (COHb ranging from 2 to 24%), and three of them had to be transferred to the hyperbaric chamber. No obvious causes could explain the CO buildup in these houses, other than nearby rock blasting that took place during the day to connect the local sewage system to the main municipal system. Again, excavations were conducted to create the natural funnel needed to ventilate the sewer system. The next morning, CO readings were negative in all six houses, and rock blasting operations then resumed. CO control measurements were concurrently conducted. Readings were normal in five houses, while they were high in the sixth house. One reading in a nearby manhole was as high as 1,100 ppm. The next morning (12 November), CO readings were still at 52 ppm in that house. Ventilating shafts had to be installed and pushed under the slab, and mechanical ventilation had to be applied to eliminate all residual CO. This case reinforces the urgency for public health authorities and other bodies concerned to address this problem (*13*).

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